Remote Manipulation of Guidewire using a Virtual Reality Device

K. FUKASAKU*, M. NEGORO, R. HIMENO*

Shinshu University; Department of Radiology, Nagoya University
*Department of Neurosurgery *The Institute of Physical and Chemical Research*

Key words: intravascular neurosurgery, telemedicine, remote surgery, virtual reality

Summary

A trial of remote manipulation for micro guidewire is reported. The system had master-slave style. When an operator manipulated the virtual torque device at the master side, a machine at the distant slave side reproduced the manipulation. At the same time, the operator could feel the force feedback from the manipulation at the slave. We could experimentally realize this remote manipulating system using a virtual reality device.

Introduction

Remote manipulation for the microcatheter system should be beneficial for remote surgery, assistance from the experts at distant hospitals, training for beginners, simulation before the procedure and, at least, decreasing radiation exposure towards the operators.

Recently advancing virtual reality (VR) technique allows us to touch some three dimensional computer graphics (3D CG) objects in the computer's memory. Such VR devices have very high spatial resolution and very accurate force restoration.

Our system consists of a pair of such virtual haptics devices and has a design of master-slave system. On manipulation of the stylus as torque device at the master side, the other device at the slave side reproduces the manipulation toward the microguidewire. The master side device can display the resistance made as the results of manipulation at the slave side to the operator. At the same time, some safety mechanisms can be installed to the system. Experimental remote manipulation by this VR system is reported.

Material and Methods

PHANToM (SensAble Technologies, Woburn, MA) was considered one of the best system for this purpose. PHANToM was one of the virtual reality devices which had very high speed force feedback and extremely accurate positioning. Using its stylus, one could feel as if touching something through a pencil. Its nominal resolution was translational: 0.03 mm, rotational in yaw & pitch were 0.002 degrees and in roll was 0.015 degrees.

We used a pair of PHANToM. At the master side, standard PHANToM (PHANToM Premium 1.0, PHANToM Stnd) was used and at the slave side, six DOF (dimension of freedom) force productive PHANToM (PHANToM 6

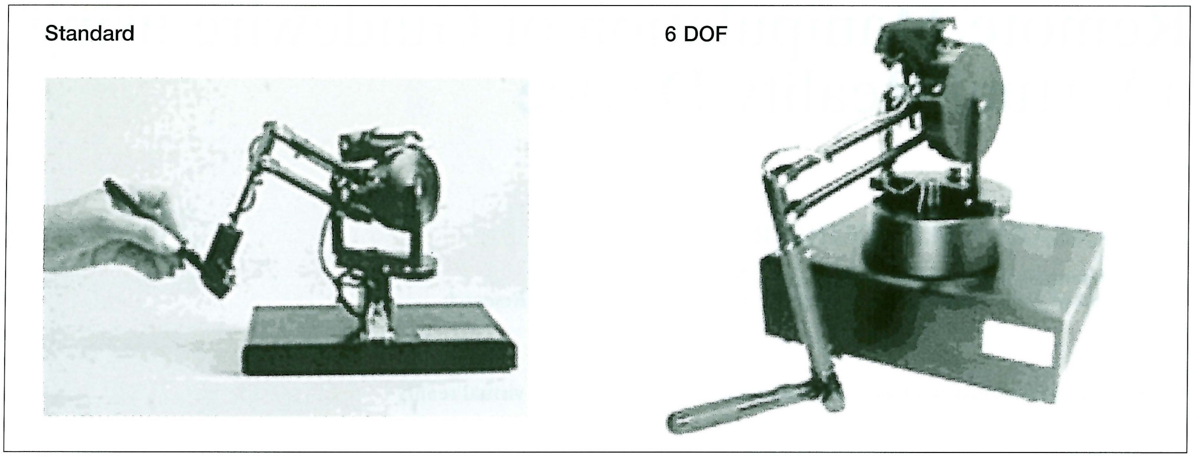


Figure 1 PHANToM standard and 6 DOF. An operator is holding stylus of PHNAToM standard. One can feel to touch objects through the stylus. Standard PHANToM can move the tip of stylus, only. Roll, pitch and yaw are not productive for the standard PHANToM. On the other hand, PHANToM 6 DOF has a thick stylus and the stylus has capability for producing roll, yaw and pitch.

DOF/1.5, PHANToM 6DOF) was selected (figure 1).

Both of 6DOF and Stnd PHANToM had six degrees (x, y, z, yaw, pitch, roll) of freedom position sensing. However, PHANToM 6DOF which was placed at the slave side, had capability to produce six degrees of freedom (x, y, z, yaw, pitch, roll) force at the stylus. On the other hand, PHANToM Stnd at master side had only three DOF force feedback (x, y, z, only. Not yaw, pitch nor roll).

One was placed at the master side and operated by human. The other was placed at the slave side and operate microguidewire accu-

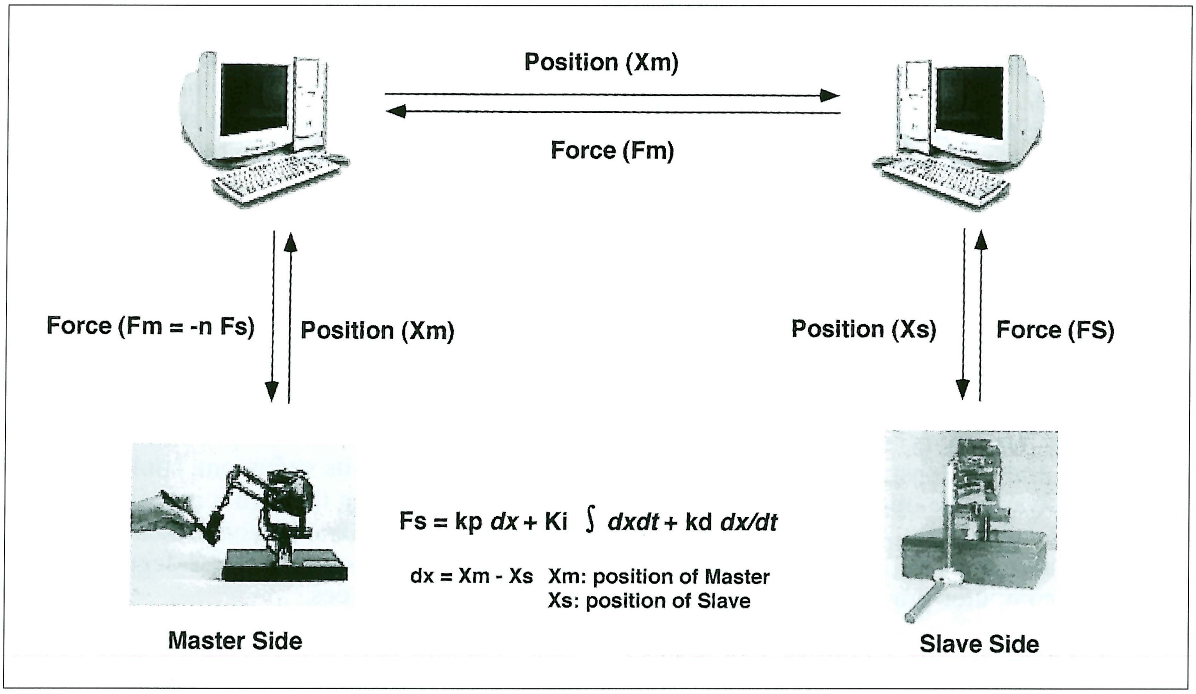


Figure 2 Calibration of the rotation. Because of the offset of the torque device, the tip of the guidewire was moved with the rotation. Pinching the guidewire and rotating the stylus automatically, the system corrects the rotational movement of stylus and wire tip.

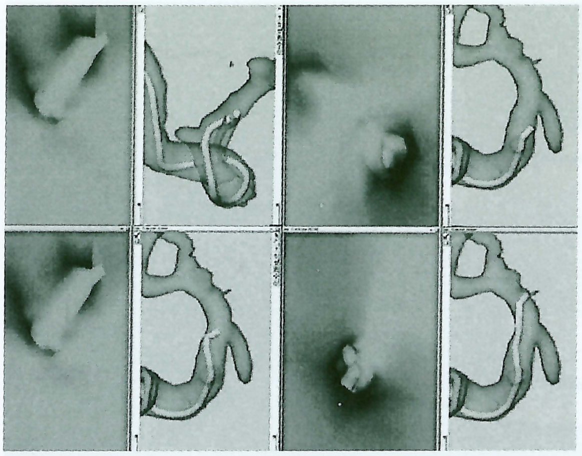


Figure 3 Sequential view of our system.On manipulation of the master side PHANToM, the slave side PHANToM 6DOF follows the movement. Note the movement of the torque device.

rately from the motion of master side. At the same time, the slave side PHANToM feedbacked the force made on manipulating the wire. Each PHANToM was contoured by Windows NT workstation through its parallel port and both of the NT machines were communicated each other through the ethernet (100 Base TE). The slave side PHANToM (6 DOF) had capability to produce rotational torque force at its stylus. So slave side PHANToM could operate guidewire.

The control program was designed like followings (figure 2). When master side PHANToM detected changing position and rotational movement of its tip, master side NT sent the new position to slave NT via ethernet. Slave NT machine calculated the force to acquire new position and sent the results to master side NT machine to produce feedback resistance and at the same time to the slave side PHANToM (6 DOF). Slave PHANToM updated its position according to the order from the NT machine.

The guidewire with torque device was bound to the stylus. Because of this offset, on rotating the stylus, the tip of guidewire moved, too. The system could measure the rotational angle and movement of tip. The system could automatically revise the rotational movement.

Our system had three security mechanisms. The first one was magnified force feedback. On feedback the force, our system could enhance the force from 0.4 to 100 times. The second was force limitation. If one operate the master in spite of certain big resistance, the slave side PHANToM froze immediately. The last one was the alarm for the rotation limit of the stylus at the slave. Because rotational movement of the slave side had the limitation of 260 degrees and of master side is 720 degrees, audio-alarm was installed to the master side. If the rotation range at the slave side were overflowed, the audio alarm warmed to the operator.

Our system also had visual monitors. It is interactive virtual endocope (figure 3). Within the vascular structure extracted from 3D CT angiography and/or 3D MR angiography, the viewpoint could move synchronously with the master side PHANToM.

Results

The guidewire at remote could be successfully operated by this system with force feedback (figure 4).

A part of the movie of the manipulation was place at http://www.asahi-net.or.jp/~ss5k-fksk/IVNR/movie.mov.

Operators could feel the force feedback very smoothly. Weight of stylus and system itself could be corrected. So one could feel just as if using torque device.

The guidewire had offset from the center of rotation of stylus at the remote site. In order to correct the discrepancy, the system could make a look up table of the shift of catheter and rotation angle of the stylus, automatically (figure 5).

Magnified feedback was also possible. However, when the magnification rate of the force elevates over four times, the movement suddenly became very shaky and the shaky movement lets the operator to stop manipulation. While both of PHANToMs were connected to the same hub, the movements of both machines were smooth and parallel.

Discussion

Merit of such remote manipulation system should be a lot.

The experts can assist other doctors at remote hospital. If needed, operation itself could be performed by these remote systems. At least, when operators manipulate master at a shield room and operate slave in DSA unit, ra-

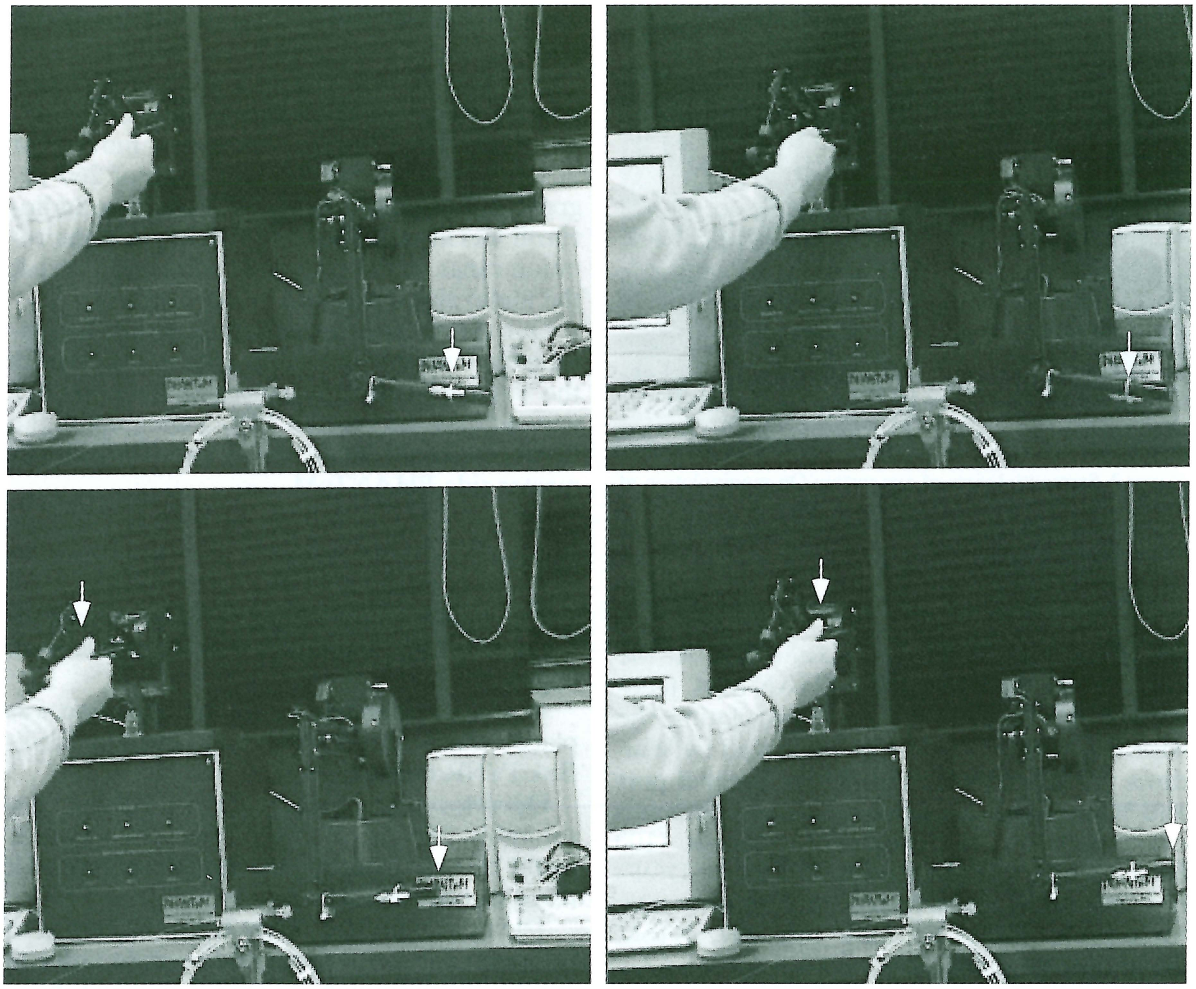


Figure 4 Virtual endoscope. Endoscopic view and surface view from 3D CTA. The view point is moved according to the manipulation of the torque device. Note the motion of the virtual wire tip.

diation exposure to the operator must be dramatically decreased.

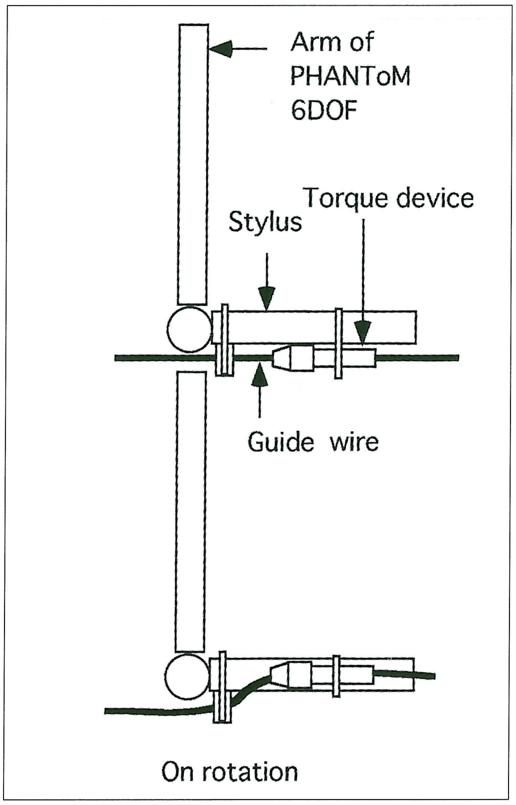
Training for our intravascular surgery is a big problem. Before computer aided system like this, we could only simulate our procedure in our mind, only. If excellent computer models or real models for each patients were established, we can simulate our strategy of treatment for each patient before real operation.

When computer aided system as ours operated the guidewire, we could assemble some safety system in it. On this system, when operator advanced the guidewire against certain resistance, the both of PHANToM froze. We cannot turn off the Phantom because if turned off, all joints of Phantom became soft and freely movable. The wire should move with gravity. This may pull back the wire, so if the system did not have enough response speed, we had possibility to penetrate the vascular structure. So, we designed to freeze.

On this design, we can only check the resistance at the torque device. If we could mount touch force sensor at the tip of wire, it must be more effective and high performance for the response.

Magnification of force feedback should be effective. We can feel more detailed resistance made by manipulation. However, the manipulation system could not be robastic enough. We designed using back stepping manner to fail to get enough stability. And 100 Base TE might be not enough for this purpose.

Recently, endoscopic remote surgical system such as da Vinci or Zeus are clinically and commercially available [1,2]. With these endoscopic



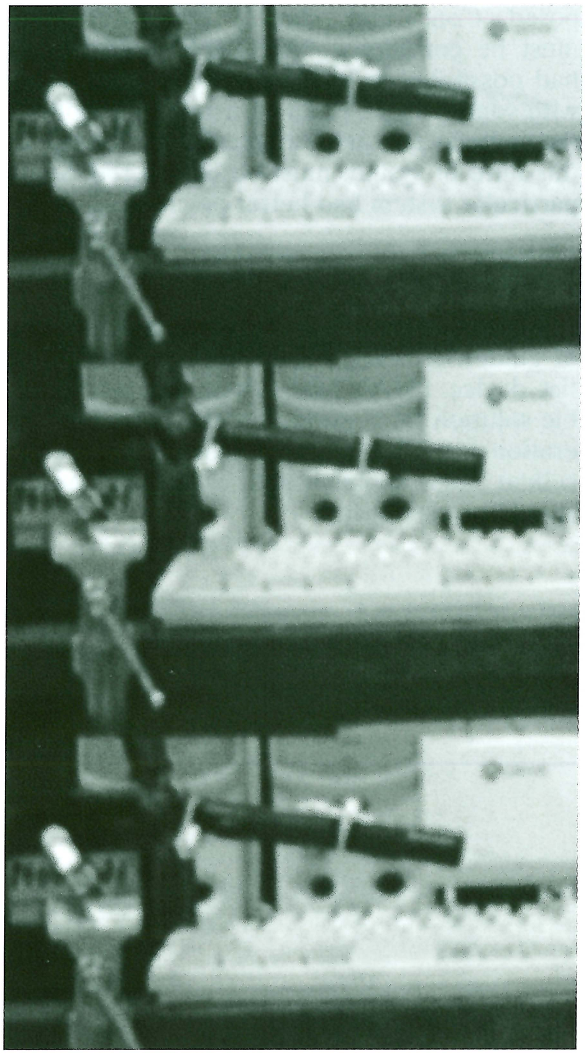


Figure 5 Diagram of the system.On the motion of master side stylus, host NT WS detects the motion then transfers the new position to the slave side. Slave side NT WS calculates the force to get the new position. Slave side NT sends the force and new position to the slave PHANToM and feeds the force back to the master side NT. The operator can feel the feedback force.

surgical systems, tremor can be disappeared. Like this assistance, when computer aided system would be available, we can operate guidewire more delicate than human can with magnified force feedback if needed.

To use these systems clinically, we should ensure several points.

One is network quality. According to our system, 100 Base TE should not be enough and the speed must be guaranteed. High quality and high speed network is essential. Because the network trouble directory becomes trouble on surgery or brings fatal results.

The other point is the responsibility. Who must be responsible for the patients? All of who are related to the procedure must be responsible. Operator beside the patient, operator at the remote site and network technician must be responsible for this type of remote surgery, I guess.

At present, the virtual endoscope was the only the visible monitor for our system. A lot of teleconference systems with internet technology are available. With these teleconference systems, manipulation at the slave side could be easily monitored from the master side, even if the master side was a distant hospital. However, comparing teleconference, monitoring for our procedure must have much quicker, much more accurate, and much more clear vision.

The high quality network was needed here, too. Image compression is an easy way to accelerate communication speed. While our procedure, we are concentrated to the tip of wire and the other place has poor motion. So, some suitable image communication should be proposed. Concerning clinical use, sterilization must be considered. Our PHANToM system had possibility to be disinfectious by covering with some bag. In order to manipulate both of the catheter and guidewire, combination use of this kind of system must be considered. Some particular system had better be create.

Conclusion

We presented a trial of remote manipulation of guidewire using PHANToM, a virtual haptics device. PHANToM system was one possible solution for remote operation. Remote operation has a lot of merit. However, more excellent and sophisticated particular system should be established.

References

1 Loulmet D, Carpentier A, d'Attellis N: Endoscopic coronary artery bypass grafting with the aid of robotic assisted instruments. J Thorac Cardiovasc Surg 118 (1): 4-10, 1999.
2 Falk V, Diegeler A: Total endoscopic computer enhanced coronary artery bypass grafting. Eur J Cardiothorac Surg 17 (1): 38-45, 2000.

Kazuaki Fukasaku, M.D.
Department of Neurosurgery
Nagoya University School of Medicine
65 Tsurumai-cho, Showa-ku,
Nagoya, 466-8550 Japan
fukasaku@med.nagoya-u.ac.jp